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# Sublexical and syntactic processing during reading: evidence from eye movements of typically developing and dyslexic readers.

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## Abstract

Skilled, typically developing readers and children with dyslexia read correct sentences and sentences that contained verb errors that were pseudo-homophones, morphological over-regularisations or syntactic errors. All errors increased looking time but the nature of the error and participant group influenced the time course of the effects. The pseudo-homophone effect was significant in all eye-movement measures for adults (N=26), intermediate (N=37) and novice typically developing readers (N=38). This effect was larger for intermediate readers than other groups in total duration. In contrast, morphological over-regularisations increased gaze and total duration (but not first fixation) for intermediate and novice readers, and only total duration for adult readers. Syntactic errors only increased total duration. Children with dyslexia (N=19) demonstrated smaller effects of pseudo-homophones and over-regularisations than controls, but their processing of syntactic errors was similar. We conclude that dyslexic children's difficulties with reading are linked to overreliance on phonological decoding and underspecified morphological processing, which impacts on word level reading. We highlight that the findings fit well within Grainger and Zeigler's (2011) grain-size model of word reading.

*Keywords: reading; phonology; morphology; dyslexia; eye-movements;*

A comprehensive model of reading must account for data from oral and silent reading across typical and atypical development. We know that skilled readers integrate multiple sources of information highly efficiently while reading, including information from orthography, phonology, morphology and syntax. We know relatively little about how this integration occurs and when it develops. This study examines these factors simultaneously in skilled, novice and intermediate typically developing readers, as well as children with dyslexia. Participants read sentences containing pseudo-homophones (e.g., *wurked*), morphological over-regularisations (e.g. *knowed*), and syntactic errors (e.g., *Last year Billy always working…*), and we examine eye-movements in response to these errors.

The power of eye-tracking data is the ability to illustrate the time course of reading behaviour. Examining this time course can, in certain cases, help us to understand the underlying processes and the ways in which readers access the lexicon at different stages of development. First fixation duration is the initial fixation duration on a word, reflecting an early stage of word processing. Gaze duration (also known as first pass duration) is the sum of all fixations on the word before moving to another word (to the left or right) and is therefore also linked to lexical processes, although not as early as first fixations. Later reading processes are revealed by eye-movement measures which include re-reading. Total duration (also known as dwell time) is the sum of all fixations that ever occur on the target word and therefore includes all processing (Hyönä, 2015) and typically reflect reanalysis and/or more strategic processing.

*Models of Word Reading*

Most models of skilled reading posit a direct, lexical route from orthography to semantics, and a second route that involves decomposition (Coltheart, 2006;

Grainger & Ziegler, 2011; Harm & Seidenberg, 2004). Typically, this decompositional route is described as phonologically mediated. For example, Coltheart's (2006) Dual Route model describes the nonlexical route as one in which word meaning is accessed using phoneme-grapheme correspondence. Dual-route models explain much of the behavioural evidence from studies of reading aloud (e.g., pseudo-homophone, frequency and regularity effects) and have been applied to data from both acquired and developmental dyslexia (Rapcsak, Henry, Teague, Carnahan, & Beeson, 2007; Ziegler et al., 2008), though only at the level of single word reading. These models do not generally address the role of morphological, semantic or syntactic information and, as a result, are likely to underestimate the complexity of the reading process.

Grainger and colleagues (Grainger, Lété, Bertand, Dufau, & Ziegler, 2012; Grainger & Ziegler, 2011) describe a model of reading that accounts for multiple sources of information, including the contribution of top-down contextualising information. A coarse-grained code provides a rapid route to semantics by focusing on the most visible and constraining features of a word (seemingly akin to the lexical route of traditional dual route models). This rapid, bottom-up activation is combined with top-down information from the sentence or passage context to enable rapid word identification. Fine-grained codes provide indirect routes to semantics using decomposition and precise information about letter order. The fine-grained code can be chunked as graphemes (corresponding to phonemes), common letter combinations and/or small morphemes. Successful reading through nonlexical access gradually forms more efficient coarse grained lexical representations through self-teaching (Share, 1995) which facilitate automatized reading in future. Grainger and colleagues (Grainger et al., 2012; Grainger & Ziegler, 2011) further describe reading development as a transition from an initial phase of serial letter-by-letter decoding, to parallel use of multiple and increasingly coarse-grain chunking units. They argue that at the start of learning to read, the nonlexical fine-grained route optimises the relationship between the written form and pre-existing linguistic codes that map to semantics. Because frequently co-occurring letters often map to both phonemes and morphemes these become the chunking units of the fine-grained code and are accessed in parallel. This view fits most models of reading acquisition, which highlight an early phase of explicit decoding giving way to later automatic word recognition (e.g. Ehri, 1995; Frith, 1985). Theories differ as to whether this is viewed as a qualitative shift or acquisition of additional processes that are used concurrently, although evidence from 9-11 year olds supports the latter (Jared, Ashby, Agauas, & Levy, 2016).

### *The development of skilled reading: Evidence from eye movements*

Previous eye-movement studies have shown that phonology is activated early during adult sentence reading (Pollatsek, Lesch, Morris, & Rayner, 1992; Rayner, Pollatsek, & Binder, 1998). Rayner et al. (1998) examined adults' eye-movements in response to homophones (*bear-bare*), pseudo-homophones (*brain-brane*) and spelling matched control words (*bare-beer*). In all cases the incorrect target increased both the earliest eye-movement measures (first fixation and single fixation durations) and later measures (gaze and total durations, regressions).

Limited eye-movement studies have examined the effects of reading ability but these suggest reading ability does affect use of phonologically mediated orthographic processes. Jared, Levy & Rayner (1999) examined eye-movements when reading passages and sentences containing homophones (e.g., *reel-real*), pseudo-homophones (e.g., *need-nead*) and spelling controls (e.g., *reel-read*). They concluded that good readers predominantly use the orthographic route to meaning, evidenced by longer gaze duration in response to both homophones and spelling controls compared to correct words. Sublexical phonological processes were only evidenced in good readers' eye-movement patterns for low-frequency, low-predictability errors. In contrast, poor readers showed a greater role for phonological processing. Poor readers' gaze durations were generally longer than good readers' and durations on pseudo-homophones, and word homophones did not differ from correct targets, whereas they were longer on pseudoword spelling controls.

### *Morphological processes in reading*

Morphemes are the smallest meaningful units within a word. Words can be broken into stems and affixes. English is a morpho-phonemic orthography with word spellings determined both by phonology and by morphological constitution. Like phonology, morpho-orthographic processes have rapid and automatic effects on word recognition (Deutsch, 1998; Drews & Zwitserlood, 1995; Rastle, Davis, & New, 2004). Morphological overlap facilitates lexical decision latencies with stimulus onset asynchronies of only 42ms. Morphological affixes can be separated into derivational affixes (those which determine the grammatical class of a word) and inflectional affixes (those which signify additional grammatical information such as tense, class or plurality). Morphology, particularly inflection, at least partly serves a grammatical function and so it is surprising that little research has examined the influence of morphology on sentence reading.

As children become more fluent readers, the text that they read increases in complexity and includes more morphologically complex words (Nagy & Anderson, 1984). Some argue that morphological skills become increasingly predictive of reading achievement through literacy development (Singson, Mahony, & Mann, 2000), but must be preceded by a more basic phonemic decoding strategy (Ehri, Cardoso-Martins, & Carroll, 2013). Conversely, others argue that use of morphology is not necessarily tied to phonological skill (Breadmore & Carroll, 2016a), and that children can use morphology from the beginning of development (Deacon, Conrad, & Pacton, 2008). However, in previous research the focus has largely been on morphological processing in spelling, rather than reading.

In dyslexia, both morphological awareness and processing are impaired in comparison to age matched peers (Deacon, Parrila, & Kirby, 2008; Deacon, Tong, & Mimeau, 2016). However, very few studies have examined morphological processing in dyslexic children using a reading-age matched design, and those which have tend to examine spelling rather than reading (Deacon et al., 2016 reviews).

Only a few studies have examined morphological processing using eye tracking. Constituent morphemes of compounds, derivations and inflections have been shown to exert independent influences on eye-movements in typical adults (Hyönä, 2015). Häikiö, Bertram & Hyönä (2010) used the boundary paradigm to examine development of Finnish compound word processing, finding that 8-year-olds already processed high frequency compound constituents in parallel. However, most of this previous research has been conducted in languages such as Finnish and Turkish which have greater morphological productivity than English. There the focus was on establishing whether morphologically complex words are stored as wholes or decomposed. Reading of inflections within sentences has received relatively less attention, and no previous work has investigated morphological over-regularisation of verbs. Morphological over-regularisations are pseudowords that can be parsed into constituent morphemes in order to access meaning. This is similar to how pseudohomophones may use phoneme-grapheme correspondence and activate semantic representations through the phonological route.

### *Syntactic processing in reading*

As children move beyond single word decoding to sentence and passage reading, they have to combine information from multiple sources. Meaning is built up across the sentence rather than solely from individual words. While morphology refers to meaning and grammar at the sub-word level, at the level of the sentence syntactic knowledge also has an impact on word recognition. It enables the reader to predict word class information, constituent morphemes and even semantic information. In fluent reading, this information is integrated simultaneously to lexical access and surrounding context is used to support interpretation of any ambiguities (Pearlmutter, Garnsey, & Bock, 1999). There is some evidence that young children read in a more word-by-word manner, performing syntactic integration and resolving syntactic ambiguity before moving on to the next word (as seen in the RA matched children in Breadmore, Krott, & Olson, 2014).

In mature readers, syntactic errors have relatively late effects on eye-movements, increasing the number of regressions on the verb but having minimal impact on gaze duration (Braze, Shankweiler, Ni, & Palumbo, 2002; Ni, Fodor, Crain, & Shankweiler, 1998). This, it is argued by some, is because these are post-lexical effects. Only a few studies have examined post-lexical effects in children’s eye-movements in English (Blythe & Joseph, 2011; Joseph & Liversedge, 2013).

### *The present study*

This paper has two aims; 1) to establish the time-course of phonologically and morphologically mediated orthographic effects, in addition to syntactic effects in sentence reading, 2) to consider the impact of reading ability and impairment on processing.

When a reader encounters a word, they can either access the whole word directly or through decomposition/co-activation of multiple sources of information. In contrast, when a reader encounters a pseudoword, rapid, direct, whole word recognition cannot be achieved because the word is not in the lexicon. Other processes must take place. To read pseudo-homophones (e.g., *klimbed*-climbed) requires phonologically mediated decomposition. In contrast, morphological over-regularisations (e.g., *knowed*-known) require morphologically mediated decomposition. We can assume that the greater the difference in time spent reading the correct target compared to pseudo-homophones, the more disruptive it is to use phonological decomposition to read the item. Similarly, the greater the difference between correct targets and morphological over-regularisations, the more disruptive it is to use morphological decomposition. In sentences containing syntactic errors the target is a real word and hence direct, whole word processing successfully activates a lexeme. However, top-down processing from the surrounding context (grammar and semantics from the sentence) conflicts with this lexical information. The time point at which we see disrupted processing indicates the point at which this conflict is detected.

Eye-movement measures enable examination of word processing in first-pass reading (increases in early eye-movement measures) and integration of information from surrounding context (increases in late eye-movement measures). We expect to see pseudo-homophone effects in early measures that reflect lexical access (first fixation and gaze duration) and effects of syntactic integration in total duration. The time course of effects for morphological over-regularisations is an open question. This condition involves integration of both lexical and syntactic information and there is insufficient pre-existing evidence to make strong hypotheses in relation to time course.

In Experiment 1 we examine typical reading development. Experiment 2 examines the impact of dyslexia. These are the first studies to examine adult and children's eye-movements in response to pseudo-homophones, morphological over-regularisations and syntactic errors. Replication with multiple participant groups enables broad generalizability across populations, adding to our understanding of skilled literacy, development and impairment.

## Experiment 1: Typical development

The aim of Experiment 1 is to examine developmental differences in automaticity of activation of phonology, morphology and grammar during reading. Eye-movements of typically developing novice (reading-age 7-9 years), intermediate (reading-age 10-12 years) and expert (adult) readers are examined and compared.

Previous research has shown that the duration and number of fixations and regressions that children make during reading decrease as age increases (Ashby, Dix, Bontrager, Dey, & Archer, 2013; Blythe & Joseph, 2011; Joseph & Liversedge, 2013). Children and poor readers do not differ from skilled readers for nonlinguistic stimuli and so differences in reading tasks reflect differences related to the process of reading, not eye-movement per se (Kirkby, Webster, Blythe, & Liversedge, 2008).

Rapid activation of meaning through well-specified lexical representations is a hallmark of skilled reading (Perfetti, 2007). Hence, we anticipate that pseudowords will result in immediate increases in early as well as late eye-movement measures for adults (Pollatsek et al.; Rayner et al., 1998). The nature of the nonlexical information required to access meaning may further influence the time course or magnitude of the pseudoword effect, reflecting automaticity. Increases in early measures (first fixation and gaze duration) are assumed to reflect immediate failure in lexical access since the pseudo-homophone does not have a lexical representation. Increases in late eye-movement measures (total duration) reflect analysis.

Little research has considered the acquisition of rapid phonological processing using eye-tracking. The few that have examined this suggest that by the age of 7 years, automatized phonological recoding prevails (Blythe, Pagán, & Dodd, 2015; Booth, Perfetti, & MacWhinney, 1999). For example, Jared, Ashby, Agauas & Levy (2016) examined children's (mean age 10;7 years) eye movements in response to errors that were homophones or spelling controls. Errors that were homophones of the correct target were less disruptive than spelling controls, both in gaze durations and go-past times. The size of the effect was not influenced by word frequency. They argue that this indicates automatic phonological processing by these intermediate readers. Unfortunately, early (single and first fixation durations) are not reported so the time-course of phonological processing remains unclear. Moreover, in the eye-movement study (Experiment 3) all targets were real words (e.g., meet/meat/mean) and therefore competing semantic representations would be activated in addition to phonological/orthographic representations. The present study controls for semantic overlap through the use of pseudowords.

Some evidence from the word recognition literature supports the view that adults use morphemes for decomposition and these are activated automatically (Chialant & Caramazza, 1995). Others argue that decomposition may be unnecessary and can take place post-lexically for syntactic reasons rather than for lexical access (Giraudo & Grainger, 2001). The prediction for the time course of the over-regularisation effect is therefore an open question. As pseudowords, whole word access must fail, but if morphemes independently support lexical access then the system might not fail immediately. Analysis could be delayed until later, when the activation of the lexical representation is sufficient to realise that the over-regularisation conflicts with the correct written word.

Learning of irregular verb tenses (the focus of the present study) has a relatively long developmental trajectory in speech and there is a phase in which children produce over-regularisations (e.g., **goed* instead of *went*; Marcus et al., 1992). Importantly, however, Marcus et al. (1992) estimated that although children produce more over-regularisations than adults, rates are still low. They estimated just 2.8% in 1st grade, 0.8% in 4th grade and 0.00004% in adult speech, and that correct irregular past tenses for the verbs are used prior to and alongside over-regularisations. Therefore knowledge of the high frequency past tenses in the present study should be secure in most of the children in the present study. That said, morphological processes become increasingly important through literacy development (Singson et al., 2000) and therefore we expect novice readers to use morphological units less.

We hypothesise that we will observe pseudo-homophone effects in both early and late measures for all readers. Novice readers rely more on phonological decoding in normal reading, and this decreases as reading ability increases. This will be reflected in a reduced pseudo-homophone effect for novice readers in comparison to intermediate or adult readers.

The hypothesis in relation to time-course of the over-regularisation effect is unclear, since to our knowledge no previous eye-tracking study has examined this effect. If over-regularisations interfere with early processing there will be an effect in early eye-movement measures. In relation to development, we hypothesise that the disruption caused by morphological over-regularisations will decrease as reading ability increases, since novice readers are slower to use morphological units.

We hypothesise that syntactic errors will affect total duration, but not early eye-movement measures, consistent with previous research (Braze et al., 2002; Ni et al., 1998). Disruption is not caused by a failure in word recognition (since the target is a word) but at the higher level of sentence processing – the word does not fit grammatically with the preceding sentence. In order to understand the sentence the reader must integrate the word with the surrounding context to infer meaning. Hence, we expect that only total duration will increase in response to syntactic errors. We do not anticipate observing developmental differences in syntactic processing. The syntactic knowledge required to recover from these errors should be acquired from speech prior to learning to read.

## *Method*

### *Participants*

All participants were monolingual native British English speakers with normal or correct-to-normal vision. None reported hearing, literacy or language impairments. Child participants for all Experiments were recruited from 20 schools across the West Midlands, UK. All of these children had standardised scores between 90 and 120 on the British Ability Scales 3 (BAS3) Word Reading Form A subscale (Elliot & Smith, 2011). Some of these children (along with others) were also included as reading-age and chronological-age matched children in Experiment 2. All experiments were approved by the University of Warwick Humanities and Social Sciences Ethics Committee and conducted in accordance with British Psychological Society guidelines. Written informed consent was obtained from adults and the parents of children. Children gave oral assent to take part.

Novice readers were 38 typically developing children with a mean reading-age of 8;3 years (6;10 – 9;3) and a mean chronological age of 7;10 years (6;2 – 9;3).

Intermediate readers were 37 typically developing children with a mean reading-age of 11;1 years (10;3 – 12;9) and a mean chronological age of 9;6 years (7;9 – 10;10).

Adult readers were 26 (four male, aged 18-25 years) undergraduate psychology students from the University of Warwick, UK who participated for partial course credit.

*Apparatus*

Sentences were presented on a BENQ XL2410-B 23.6 inch widescreen monitor with a 60Hz refresh rate, 32 bits per pixel (SVGA resolution 1024x768), connected to an Intel i5-2430M CPU at 2.40GHz Toshiba Satellite Pro R850-19H. Sentences were presented in 18pt Monaco (monospaced sans-serif) font, black on grey (to minimise eye strain RGB 254, 254, 254), at a viewing distance of 70cm. Display of the experiment was controlled by ExperimentBuilder™ software (Version 1.10.165; SR Research Ltd., Ontario, Canada). Participants read binocularly but monocular eye-movements were recorded using an SR Research Eyelink 1000 desktop mount eye-tracker with a 35mm lens and a data rate of 500Hz. Participants leaned against chin and forehead rests to eliminate head movements. The distance from the forehead rest to the camera screw was 54cm.

*Stimuli and design*

Half of all sentences were correct and half contained errors (50% pseudowords and 50% syntactic errors). For pseudowords the target verb was misspelled (e.g., "*Last year the school play endid with a big dance"*). In sentences with syntactic errors, the target verb was the wrong tense for the preceding sentence context (e.g., *"Last year the school play end with a big dance"*). Thirty-six sentence frames were manipulated to create four trials per sentence frame – a pseudoword, a syntactic error and matched controls for both types of error with the target verb presented in its correct form. For syntactic controls it was often necessary to add or alter a word in the sentence before the target verb (e.g., pseudoword control *"Last year the school play ended with a big dance",* syntactic control *"This year the school play will end with a big dance"*). The words after the target verb were identical in all conditions.

Pseudoword errors were of two types; 18 morphological over-regularisations of an irregular past tense verb (e.g., *grown/growed*) and 18 pseudo-homophones (e.g., *ended/endid*). Nine pseudo-homophones had errors in the root (e.g., *"klimbed"*) and nine in the suffix (e.g., *"pickt"*). A complete list of stimuli is provided in Appendix 1.

Morphological over-regularisations and pseudo-homophones (i.e., pseudoword conditions) were matched for bigram frequency (type and token - Davis, 2005), length (number of letters) and root frequency. Correct targets in the two pseudoword conditions were matched for CELEX written frequency (Baayen, Piepenbrock, & van Rijn, 1995; Davis, 2005) and sentence frames contained the same number of characters before and after the verb (see Table 1).

*** Table 1 about here ***

Stimuli were divided into two lists, such that each participant read 72 sentences (9 pseudo-homophones, 9 morphological over-regularisations, 18 syntactic errors and 36 matched correct sentences. Hence, both error (error, correct target) and error type (pseudo-homophone, over-regularisation, syntactic) were within-participant factors and participants viewed each sentence frame twice – once with the correct verb and once with a pseudoword/syntactic error to enable direct comparison of response to the correct and incorrect verb. Trial order was randomised between participants to minimise practice effects. Simple comprehension questions followed 20/72 sentences to encourage reading for comprehension.

*Procedure*

Participants received written instructions (reiterated verbally) explaining the procedure. Each sentence was preceded by a drift check circle in the centre of the screen, followed by a gaze contingent black square at the location where the sentence would begin. They were asked to read the sentence silently and normally and then to look down to a grey gaze contingent box in the bottom right corner. After 20/72 sentences they then received a comprehension question, before beginning the next trial. After an initial calibration using a nine point grid, there followed a reminder of the instructions and two practice trials before commencement of experimental trials. Participants were instructed that they could take a break when the circle was on screen. The experimenter recalibrated at this point as necessary. Most children completed the eye-tracking session in 20-30 minutes, and adults in about 15 minutes.

## *Results and Discussion*

Eye-data was prepared using the four-stage data cleaning procedure in DataViewer™ software (Version 2.2.1; SR Research Ltd., Ontario, Canada). The principle here is to merge short fixations that are in close proximity to one another before finally removing very short, isolated fixations. Fixations shorter than 80ms were merged with fixations within one character width. Then fixations shorter than 40ms were merged with fixations within three character widths. Finally, remaining fixations shorter than 80ms or longer than 1200ms were removed. Trials were visually inspected and removed due to tracker loss or because the participant had not read the whole sentence – trials were only included if there were fixations before, after and on the target region. 6569/7272 trials remained after data cleaning (9.6% of trials removed for novice readers, 8.5% for intermediate readers, 11.5% for adult readers). Performance on the comprehension trials was good in all groups (mean accuracy 89%, 93% and 98% in each group). Outliers were finally removed from eye-movement measures involving the summation of multiple fixations (gaze and total duration), removing data that was more than 2.5SDs from each group mean. This affected a further 3.0% of novice readers' gaze and 2.4% total durations; 2.8% and 2.4% of intermediate readers'; and 3.0% and 2.7% of adults'.

Data were analysed using linear mixed effects modelling with maximum likelihood using the lme4 package (Bates, Maechler, Bolker, & Walker, 2014 version 1.1-7) in R (R Core Team, 2014 version: 3.1.1). Full models included random intercepts for participants and items. When selecting which random slopes to include, we followed the procedure outlined by Barr, Levy, Scheepers & Tily (2013), keeping models logically maximal. Random slopes by participants are illogical for between-subjects factors. Random slopes by items are illogical for between-items factors. Random slopes cannot be logically defined for interactions with both within and between-subjects factors. Hence, the full model initially had the structure:

Dependent variable ~ Participant Group*Verb +(1+Verb|Participant) +(1+Participant Group|Item)

The significance of each fixed factor was calculated using likelihood ratio tests comparing full and null models with identical random structure. Hence, significance of the interaction was assessed by comparing the full model to a model without the interaction term (anova(Full Model, Null Interaction Model)). Fixed effects of Verb and Participant Group were compared to the model with additive fixed effects, rather than the interaction (main effect of Verb assessed by anova(Null Interaction Model, Null Verb Model), main effect of Participant Group was assessed by anova(Null Interaction Model,Null Participant Group Model). If any full or null model failed to converge, random slopes were removed from all models, first by-items (i.e., +(1+Participant Group|Item) becomes +(1|Item)). If convergence still could not be achieved we then removed random slopes by-participants (i.e., +(1+Verb|Participant) becomes +(1|Participant)). Adult's eye-movements are substantially shorter than children's and eye-tracking data is often skewed. Hence, model comparisons were conducted on log transformed data. Raw data and t-values are reported in Table 2 and Figure 1 to aid interpretation. Note that these t-values also offer an alternative measure of significance. Table notes indicate which random slopes were included in the models of raw data. R scripts and minimal datasets are provided in supplementary materials.

Contrast coding was set up such that the baseline for the fixed effect of participant group was adults (order of contrast coding was adults, intermediate, novice readers). The correct target was the baseline for the fixed effect of verb. Hence, the estimated coefficient (β) for the intercept can be interpreted as adult readers' average on correctly spelled verbs. The sum of intercept β plus intermediate β reflects intermediate readers' average on correctly spelled verbs (or, for novice readers, the sum of intercept β plus novice β). A positive verb error β reflects increased looking time when the verb contains an error, and the summed intercept β plus verb error β provides the average duration on these errors.

These procedures were repeated on the following dependent variables measured on the interest area corresponding to the target verb; first fixation, gaze and total duration. LME summary statistics can be found in Table 2. First we examine effects of pseudohomophones, then over-regularisations and finally syntactic errors. The Bonferroni corrected criterion of .05/3 = .0167 is applied to all analyses by groups consistent with von der Malsburg and Angele (2016).

*** Table 2 about here ***

*Pseudo-homophones*

Consistent with our hypotheses and previous research (Pollatsek et al.; Rayner et al., 1998), both effects of participant group and verb were highly significant on pseudo-homophones for all eye-movement measures; log first fixation (random slopes by participant) $\chi^2(2) = 50.55$, $p < .0001$ and $\chi^2(1) = 24.17$, $p < .0001$; gaze (random slopes by participant) $\chi^2(2) = 76.66$, $p < .0001$ and $\chi^2(1) = 43.91$, $p < .0001$; total (random slopes by participant and item) $\chi^2(2) = 49.55$, $p < .0001$ and $\chi^2(1) = 93.79$, $p < .0001$. The interaction, however, only emerged in total duration; log first fixation $\chi^2(2) = 0.74$, $p = .7$; gaze $\chi^2(2) = 3.26$, $p = .2$; total $\chi^2(2) = 15.35$, $p < .0005$.

Follow-up analyses to investigate this interaction compared each pair of participant groups (Bonferroni corrected criterion .05/3 = .0167). This revealed that the interaction was not significant in log total duration when comparing adult and novice readers $\chi^2(1) = 1.08$, $p = .3$; but was when comparing intermediate and adult readers $\chi^2(1) = 14.40$, $p = .0001$; as well as intermediate and novice readers $\chi^2(1) = 7.95$, $p = .005$. Simple effects analyses examined the size of the effect in each participant group (see Table 3). The β for total duration revealed that the magnitude of the pseudo-homophone effect was greater for intermediate readers than any other group. Examining the mean total duration plotted in Figure 1, intermediate reader's total duration on correctly spelled verbs are much shorter than novice readers'. Intermediate reader's response to pseudo-homophone errors is more similar to novices. They are faster at reading real words but still slow to recover from errors. Adult readers are fast in both conditions, hence the pseudo-homophone effect appears relatively small. Crucially though, although the magnitude of the effect varies, the pseudo-homophone effect was highly significant for all participant groups, in all measures.

*** Table 3 and Figure 1 about here***

*Morphological over-regularisations*

The main effect of verb for over-regularisations was significant in every eye-movement measure; log first fixation $\chi^2(1) = 4.12$, $p = .04237$; gaze $\chi^2(1) = 34.83$, $p < .0001$; total $\chi^2(1) = 60.95$, $p < .0001$. All durations became shorter with development. The main effect of participant group was significant in all measures; log first fixation $\chi^2(2) = 35.58$, $p < .0001$; gaze $\chi^2(2) = 40.45$, $p < .0001$; total $\chi^2(2) = 44.47$, $p < .0001$. The interaction between participant group and verb was only significant in gaze duration; log first fixation $\chi^2(2) = 0.05$, $p = 1.0$; gaze $\chi^2(2) = 9.42$, $p = .009$; total $\chi^2(2) = 1.76$, $p = .4$.

Follow-up analyses examined the nature of the interaction in log gaze duration by comparing each pair of participant groups (Bonferroni corrected criterion 0.0167). The interaction between participant group and verb was significant when comparing adult and novice readers $\chi^2(1) = 9.34$, $p = .002$; but not when comparing intermediate and adult readers (no random slopes) $\chi^2(1) =2.57$, $p = .1$; or intermediate and novice readers $\chi^2(1) = 2.99$, $p = .08$. LME statistics by participant group (see Table 3) reveal that the effect of the over-regularised verb error was significant in gaze duration for both intermediate and novice readers, but did not emerge until total duration for adults[1]. This suggests that morphological over-regularisation does not cause a problem in first-pass reading for adult readers, but emerges later.

*Syntactic errors*

The same LME procedures were repeated to examine the effect of syntactic errors. The main effect of verb was again significant in all measures; log first fixation $\chi^2(1) = 4.76$, $p = .029$; gaze (no random slopes by items) $\chi^2(1) = 5.98$, $p = .0145$; total $\chi^2(1) = 77.27$, $p < .0001$. Consistent with all analyses, durations became shorter with development. The main effect of participant group was significant in all measures; log first fixation $\chi^2(2) = 41.55$, $p < .0001$; gaze $\chi^2(2) = 68.43$, $p < .0001$; total $\chi^2(2) = 59.84$, $p < .0001$. The interaction between participant group and verb was not significant in early measures but was in total duration; log first fixation $\chi^2(2) = 0.24$, $p = .9$; gaze $\chi^2(2) = 0.36$, $p = .8$; total $\chi^2(2) = 10.10$, $p = .0064$.

Follow-up analyses examined this interaction in log total duration by comparing each pair of participant groups (Bonferroni corrected criterion 0.0167). The interaction was significant when comparing novice and intermediate readers $\chi^2(1) = 9.03$, $p = .0027$; but not when comparing adults and novices, or adults and intermediate readers; $\chi^2(1) = 3.31$, $p = .07$; $\chi^2(1) = 1.43$, $p = .2$. The LME statistics by participant group (Table 3) and the plot of mean total duration in each condition (Figure 1) reveal that for adults and intermediate readers the syntactic effect was only significant in total duration. This is similar to what was seen for intermediate readers in the pseudohomophone condition. Intermediate readers are faster than novices at reading syntactically correct verbs but recovery from errors is slow.

[1] We investigated whether adults' gaze durations in response to over-regularisations changed strategically over the course of the study by including the additional fixed factor order (first half of experiment, second half of experiment). Neither the main effect ($p = .1599$) nor the interaction ($p = .323$) were significant.

The duration of all eye-movement measures decreased as reading ability increased. Moreover, as hypothesised, the pseudo-homophone effect was significant in both early and late measures for all readers. This indicates that pseudo-homophones interfered with lexical access from the earliest stages of processing, even for novice readers. Contrary to our expectations, it was the intermediate readers who showed the largest pseudohomophone effect in total duration. This is due to rapid processing of correctly spelled verbs and slow recovery from spelling errors. A similar developmental pattern was observed in total duration in response to syntactic errors, so we return to this later.

A different pattern was seen with morphological over-regularisations. The over-regularisation effect was weaker in first fixation duration. This could either be because the over-regularised verb is constructed from morphemes, or simply because the beginning of the word is spelled correctly. The over-regularisation effect emerged in gaze and total duration for intermediate and novice readers, but only total duration for adults. This suggests that morphological over-regularisation causes disruption later, particularly for adults. This suggests that adults are able to read on in the sentence and use context and grammar to support recovery or disambiguate the over-regularisation error. This could be achieved by activating multiple possible representations or nonlexical codes. However, this is not always successful, given the late effect in total fixation duration for them as well. Children, on the other hand, seem to read in a word-by-word manner, trying to resolve word recognition difficulties before moving on to the next word.

For all participants, the syntactic effect emerged even later than either pseudoword error, only reaching significance in total duration. The disruption caused by the over-regularisation error is not, therefore, simply due to syntactic ambiguity. Syntactic errors, do not cause failure in word recognition, but disrupt processing because the word does not fit grammatically with the sentence. Contrary to our predictions, we observed developmental differences in syntactic processing, with intermediate readers showing a larger effect than novice readers (in total duration). The same pattern was observed for pseudohomophones. In both cases, intermediate readers processed correct targets much more rapidly than novice readers, but were more similar in terms of their slow recovery from errors. This suggests that intermediate readers are able to use lexical codes to read correct verbs rapidly, like adults. Once adults have decided what word was intended, they are more confident in moving on and do not have to keep rechecking the verb error. In contrast, when intermediate readers have uncertainty it takes longer to recover.

## Experiment 2: Dyslexia

Experiment 2 compares children with dyslexia to reading-ability and chronological-age matched typically developing peers. We examine whether these individuals encounter specific difficulties with using the phonologically mediated orthographic route to meaning, accessing meaning through decomposition in general or more generalised reading difficulties. If dyslexic children differ from age-matched but not ability matched children, this indicates a developmental delay but one which is consistent with typical literacy development and not unique to dyslexia. If dyslexic children differ from ability matched children, this indicates an atypical course of development.

Dyslexia is a specific impairment in learning to read, beyond that expected based on intelligence, socio-economic status, educational opportunity or sensory impairment (Vellutino, Fletcher, Snowling, & Scanlon, 2004). Dyslexia is commonly associated with phonological impairments (Snowling, 2000). Recently it has been argued that dyslexia has multiple, probabilistic causes and accordingly not all children with dyslexia will necessarily have difficulty with phonology (Pennington et al., 2012). Most models of reading would predict that such phonological impairments can be expected to impact on both early and later reading processes. Share's (1995) self-teaching hypothesis makes this explicit, arguing that experience of successful phonological recoding enables the reader to form word-specific orthographic representations that facilitate direct lexical access, and hence, individuals with dyslexia would show difficulties in both phonological recoding and direct lexical access. These difficulties should result in a smaller pseudo-homophone effect due to dyslexic individuals not showing a lexical advantage for the correctly spelled words. Instead both correct and pseudo-homophone targets are processed in the same way.

There is mixed evidence regarding whether morphological processing is impaired (Breadmore & Carroll, 2016a, 2016b; Carlisle, 1987; Hauerwas & Walker, 2003) or spared (Bourassa & Treiman, 2008; Bourassa, Treiman, & Kessler, 2006) in dyslexia. The present study will give insight to this debate. The null hypothesis, that morphological processing is not impaired in dyslexia, predicts that the over-regularisation effect will emerge in gaze duration as observed in the intermediate and novice readers in Experiment 1.

Dyslexic children are not expected to have difficulty with syntactic processing. Therefore, we do not anticipate finding any differences in the time course of response to syntactic errors in comparison to their peers.

## *Method*

Experiment 2 had identical methodology to Experiment 1. Participants were recruited from the same schools.

### *Participants*

The dyslexic sample comprised of 19 children who met the criteria for dyslexia. Three further participants completed the task but were removed from the analyses because of a large proportion of unusable trials in the data – either the sentence had not been read, there was poor calibration due to too much head movement, or equipment failure. Each child with dyslexia was pairwise matched to two control children with typical reading abilities; a) by reading-age and b) by chronological-age. Control children had standardised scores between 90 and 120 on the BAS3 Word Reading Form A subscale (Elliot & Smith, 2011) and were monolingual native English speakers. None of the dyslexic or typically developing children reported hearing impairment or a history of repeated ear infections.

#### *Dyslexia.*

The dyslexic group included 19 children (12 female) with a mean chronological-age of 9;6 years (range 8;2-10;9). All of these children had standardised scores below 90 on BAS3 Word Reading subtest[2]. Their mean reading-age was 7;10 years (range 6;10-8;9). Nonverbal IQ as measured by BAS3 Matrices was in the normal range and the mean percentile was 50.9 (SD 26.3). Mean score on the Clinical Evaluation of Language Fundamentals 4 (CELF4 - Semel, Wiig, & Secord, 2006) Phonological Awareness Subscale was 70 (SD 9; maximum score 85).

[2] Although our criteria of a standard score below 90 may seem lenient in the general population, it is important to recognise that these participants' classmates were performing better than the standardisation sample - the standardisation sample have a mean of 100 and an SD of 15, compared to 104 and 7 for typically developing peers sampled across the RA and CA groups, and 85 and 4 for children with dyslexia

*Chronological-age matched.*

Nineteen typically developing children (8 female) were pairwise matched to the dyslexic children on the basis of chronological-age (henceforth, CA); $t(36) = -0.1$, $p = 1.0$. CA children had a mean chronological age of 9;6 years (range 8;3-10;10) and a mean reading-age of 10;8 years (9;3-12;3). Mean standardised score on the BAS3 Word Reading subtest was 106 (SD 5). Mean percentile on BAS3 matrices was 58.1 (SD 29.9). Mean score on CELF4 Phonological Awareness Subscale was 72 (SD 4).

*Reading-age matched.*

Nineteen typically developing children (12 female) were pairwise matched to the dyslexic children on the basis of reading-age (henceforth, RA); $t(36) = -0.8$, p = .4. They had a mean chronological age of 7;10 years (range 6;2-9;3) and a mean reading age of 8;0 (range 6;10-8;9). Mean BAS3 Word Reading Subscale standardised score was 102 (SD 8). Mean percentile on BAS3 matrices was 56.3 (SD 33). Mean score on CELF4 Phonological Awareness Subscale was 68 (SD 7). Dyslexic children showed phonological awareness scores in line with their RA controls.

## *Results and Discussion*

In total 3751/4104 trials remained after data cleaning using the same procedures as Experiment 1 (6.6% of trials from the dyslexic group, 8.8% from RA matches and 10.5% of CA matches removed). Outliers (more than 2.5SD from the group mean) were removed from the eye-movement measures which involve summation of fixations (gaze duration and total duration). This affected a further 3.7% of dyslexic children’s gaze and 3.1% of total durations; 2.3% and 2.8% of CA children’s; 2.7% and 2.6% of RA children’s. Mean accuracy in comprehension trials was good in all groups (mean accuracy of 90%, 89% and 95% respectively). Analyses were conducted following the same procedures as Experiment 1. The dyslexic children formed the baseline for the fixed factor of participant group, followed by CA then RA matched controls.

To understand interactions, we compared children with dyslexia to their CA and RA matched peers separately. There are both statistical and theoretical reasons to conduct separate analyses rather than an omnibus analyses. The groups have been individually pairwise matched, with separate comparisons planned a priori to distinguish between effects of age and reading-ability. Including all three participant groups in a single analysis limits variance and introduces overlap between groups (for example, in this study the dyslexic and CA children are matched for age, and RA children partially overlap in age). The participants have not been randomly sampled but have been carefully selected on the basis of various characteristics. Hence, throughout these analyses, in order to prevent Type II errors we used a more lenient criterion to follow-up interactions ($p < .1$).

LME model summaries for the omnibus analyses comparing each participant group are presented in Table 4. Mean total duration for each condition and participant group are plotted in Figure 2. Likelihood ratio test statistics are presented by participant group in Table 3 (applying a Bonferroni corrected criterion of .05/3 = .0167).

*** Table 4 about here ***

*Pseudo-homophones*

In contrast to the findings from Experiment 1, the effect of pseudo-homophone verb was not significant in first fixation duration or gaze duration for children with dyslexia, only in total duration (Table 3). Children with dyslexia did not process correctly spelled words any more rapidly than pseudo-homophones. Omnibus analysis (see Table 4) including the fixed effect of participant group (dyslexia, CA, RA) revealed that there was a significant main effect of participant group for all eye movement measures; log first fixation $\chi^2(2) = 14.51$, $p = .0007$; gaze (no random slopes) $\chi^2(2) = 42.86$, $p < .00001$; total duration $\chi^2(2) = 17.63$, $p = .0001$. The main effect of verb was not significant in log first fixation duration but was in gaze and total duration $\chi^2(1) = 1.75$, $p = .1855$; $\chi^2(1) = 19.37$, $p = .0001$; $\chi2(1) = 61.17$, $p < .0001$. The interaction was only significant in total duration, although there was a trend in first fixation duration; $\chi^2(2) = 4.05$, $p = .1321$; $\chi^2(2) = .40$, $p = .82$; $\chi^2(2) = 8.65$, $p = .01321$.

In first fixation duration, when comparing dyslexic and CA matched children, only the main effect of participant group was significant; $\chi^2(1) = 8.27$, $p = .0040$; verb $\chi^2(1) = 0.11$, $p = .74$; interaction $\chi^2(1) = 2.47$, $p = .1158$. When comparing dyslexic and RA matched children, neither main effect was significant but there was a trend for a significant interaction; group $\chi^2(1) = 0.31$, $p = .6$; verb $\chi^2(1) = 0.49$, $p = .5$; interaction: $\chi^2(1) = 3.28$, $p = .0702$.

In total duration, when comparing dyslexic and CA matched children, the main effects of participant group and verb, and interaction were significant (random slopes by participant); group $\chi^2(1) = 19.79$, $p < .0001$; verb $\chi^2(1) = 36.23$, $p < .0001$; interaction $\chi^2(1) = 7.37$, $p = .0066$. When comparing children with dyslexia to RA matched controls, the main effect of participant group was not significant, but both the main effect of verb and the interaction were significant; group: $\chi^2(1) = 0.71$, $p = .40$; verb: $\chi^2(1) = 37.92$, $p < .0001$; interaction: $\chi^2(1) = 5.08$, $p = .0242$.

*** Figure 2 about here ***

In contrast to Experiment 1, the pseudo-homophone effect was not significant in first fixations or gaze durations for dyslexic children. However, the magnitude of this effect did not differ from CA or RA matched peers. By total duration, the magnitude of the pseudo-homophone effect did differ between participant groups. Figure 2 illustrates that compared to CA matched peers, dyslexic children had longer total durations for both correct verbs and pseudo-homophones, but a relatively smaller pseudo-homophone effect. In comparison to RA matched peers, dyslexic children were slower to read correctly spelled targets but faster to read pseudo-homophone errors. Again, this resulted in a smaller pseudo-homophone effect for dyslexic children.

*Morphological over-regularisations*

For children with dyslexia, the effect of morphological over-regularisations was not significant in log first fixation or gaze duration, but was in total duration (see Table 3). Omnibus analyses (see Table 4) including the fixed effect of participant group (dyslexia, CA, RA) revealed a significant main effect of participant group in all eye movement measures; log first fixation (no random slopes) $\chi^2(2) = 13.79$, $p = .0001$; gaze (no random slopes) $\chi^2(2) = 33.15$, $p < .00001$; total $\chi^2(2) = 28.92$, $p < .00001$. Similarly to Experiment 1, the main effect of verb was not significant in log first fixation duration, but was in gaze and total duration; first fixation $\chi^2(1) = 2.52$, $p = .1122$; gaze $\chi^2(1) = 30.60$, $p < .00001$; total duration $\chi^2(1) = 26.04$, $p < .00001$. Despite a trend in gaze duration, none of the interactions were significant; first fixation: $\chi^2(2) = 1.01$, $p = .6$; gaze: $\chi^2(2) = 4.40$, $p = .1108$; total duration: $\chi^2(2) = 0.35$, $p = .8$.

Since there was a trend for an interaction in the omnibus analyses, we followed up effects in gaze duration. Comparing dyslexic and CA matched controls, main effects of participant group and verb were significant; group $\chi^2(1) = 29.61$, $p < .0001$; verb $\chi^2(1) = 9.70$, $p = .0018$. The interaction was not; $\chi^2(1) = 0.39$, $p = .5$. Comparing dyslexic children and RA matched controls indicate significant main effects of participant group and verb (no random slopes); group $\chi^2(1) = 6.42$, $p = .0113$; verb $\chi^2(1) = 18.91$, $p = .00001$ and a marginal interaction; $\chi^2(1) = 3.75$, $p = .0529$. Children with dyslexia had longer gaze duration than RA matched children on both correctly spelled and over-regularised verbs. The magnitude of the effect was marginally smaller for dyslexic children.

*Syntactic errors*

As found in Experiment 1, the effect of syntactic errors did not emerge until total duration for dyslexic children (see Table 3). Similarly, in the omnibus analysis including all three participant groups (dyslexia, CA, RA, see Table 4), the main effect of verb was not significant in log first fixation or gaze duration, but was in total duration; first fixation $\chi^2(1) = 0.83$, $p = .4$; gaze $\chi^2(1) = 2.26$, $p = .1329$; total duration (no random slopes by items) $\chi^2(1) = 31.81$, $p < .00001$. The main effect of participant group was significant in all measures; $\chi^2(2) = 19.60$, $p = .00005$; $\chi^2(2) = 33.99$, $p < .00001$; $\chi^2(2) = 28.58$, $p < .00001$. The interaction was not significant; $\chi^2(2) = 0.85$, $p = .7$; $\chi^2(2) = 0.5$, $p = .8$; $\chi^2(2) = 1.19$, $p = .6$. Hence, although children with dyslexia were generally slower readers, syntactic processing was similar to CA and RA matched peers.

In summary, the main effect of group was significant in all analyses. Dyslexic children generally made more and longer fixations. Nonetheless, when only dyslexic and RA children were compared, the main effect of group was very rarely significant[3]. Therefore, fluency is linked to reading-ability rather than dyslexia per se. Dyslexic children's eye-movement patterns were surprisingly similar to typically developing children, particularly in relation to their response to morphological over-regularisations and syntactic errors. The main difference emerged in their response to pseudo-homophones. Dyslexic children did not show the pseudo-homophone effect in first fixations and the effect was only marginal in gaze duration. This effect had been observed in every measure in every participant group in Experiment 1. Nonetheless, dyslexic children did not differ significantly from CA or RA matched controls on first fixation or gaze duration. In total duration though, the magnitude of the pseudo-homophone effect was significantly smaller for dyslexic children compared to both RA and CA matched peers. Dyslexic children have generally longer looking times on correct targets and don't seem to show as much of an advantage for real words over pseudo-homophones in earlier eye-movement measures. One possible interpretation of this is that dyslexic children use phonological decoding more, slowing down all of their reading.

## General Discussion

These studies tested phonologically and morphological mediated orthographic processing in addition to syntactic processing across typical and atypical development. In two experiments we examined eye-movements during silent sentence reading with different participant groups; typically developing novice, intermediate and adult readers (Experiment 1), and children with dyslexia (Experiment 2).

[3] Main effect of participant group (dyslexia, RA) was significant only for syntactic errors in log fixation duration; pseudohomophones $\chi^2(1) = 0.31$, $p = .6$; over-regularisations $\chi^2(1) = 1.60$, $p = .21$; syntactic errors $\chi^2(1) = 3.90$, $p = .04816$. The difference was significant in all conditions for log gaze duration; pseudohomophones $\chi^2(1) = 3.96$, $p = .04663$; over-regularisations $\chi^2(1) = 7.58$, $p = .005895$; syntactic errors $\chi^2(1) = 5.52$, $p = .01879$. The effect of participant group was not significant in log total duration; pseudohomophones $\chi^2(1) = 0.71$, $p = .40$; over-regularisations $\chi^2(1) = 2.64$, $p = .1039$; syntactic error $\chi^2(1) = 1.14$, $p = .3$.

We replicate and extend some generalised developmental effects in eye-movements (Ashby et al., 2013; Blythe & Joseph, 2011; Joseph & Liversedge, 2013) – low ability readers, whether younger or dyslexic, generally showed less fluency in reading and this was reflected by looking at target words more often and for longer. This study adds to the current literature by ascribing these differences in fluency to a stage of literacy development rather than age or dyslexia per se. Beyond this, the results allow us to get a better understanding about the time-course of phonological and morphological processing in word recognition. Misspelled words that required phonological processing caused early and late disruption of reading, while misspellings that required morphological resolution did not cause disruption of the earliest eye-movement measures. This may suggest that both children and adults can quickly decompose words into constituent morphemes.

### *Phonologically mediated orthographic processing*

Consistent with our hypotheses, the pseudo-homophone effect was significant from the earliest eye-movement measures for adults and typically developing children. This is an indication that even novice readers have some automatic word recognition skills for correctly spelled words. This mechanism is not reliant on decoding alone, as it is disrupted by a misspelling, even when it is a pseudo-homophone. This therefore allies to Coltheart's (2006) 'lexical route' or Grainger's (Grainger & Ziegler, 2011; Grainger et al., 2012) 'coarse-grained route' for word recognition and suggests this develops relatively quickly (by 7-9 years of age).

In Experiment 1, the magnitude of pseudo-homophone effects increased over the eye-movement measures. By total duration, the pseudo-homophone effect was significantly larger in intermediate readers than novice or adult readers. This, we argue, is due to intermediate readers being able to access correct verbs rapidly (using the lexical route, like adults), but finding it relatively difficult to resolve misspelled words. Intermediate readers are still in the stages of regularly encountering unknown words in text, and it is therefore important for them to read these words carefully to verify them. Adults, on the other hand, encounter unknown words relatively rarely and it may be more appropriate for them to make a quick decision on misspelled words. Novice readers are generally slower but also take longer to decide what word was intended when they encounter an error.

In Experiment 2, the pseudo-homophone effect was not significant in dyslexic children’s first fixation duration, was marginal in gaze but was significant in total duration. Only in total duration, however, was the pseudo-homophone effect was significantly reduced in dyslexic children in comparison to controls. Dyslexic children were slower than both groups at reading correct words, and very similar to RA controls in response to pseudohomophones. This then suggests that dyslexic children are using the same mechanisms to read both correct verbs and pseudohomophones and that they rely more on phonological decoding in normal reading than typical readers. It is surprising to find differences in the magnitude of the pseudohomophone effect in total duration but not in first fixation. There are at least two possible explanations for this finding. It could be that initially, all participants rely equally on phonological decoding but that on second-pass reading typically developing children integrate other processes whereas dyslexic children continue to rely largely on phonological decoding. Another possible explanation is that typically developing children immediately noted something odd about the pseudohomophonic words during first-pass reading and that led them to return to the word for longer. That would suggest that typically developing children process more orthographic information during first-pass reading than dyslexic children. Or, put the other way, dyslexic children are more restricted and reliant on phonological processes even from first-pass reading. Further research should attempt to disentangle these two possible explanations for this effect. Some caution should be exercised in interpreting the pseudo-homophone effect in dyslexic readers however, since the control groups did not demonstrate the early pseudo-homophone effects shown in Experiment 1, suggesting a lack of power in the early measures (sample size is smaller in Experiment 2 than Experiment 1).

### *Morphologically mediated orthographic processing*

The effect of morphological over-regularisation was not significant in first fixation duration for any participant groups, and was only marginal overall. This suggests that initial lexical processing of over-regularisations was very similar to real word targets. The effect was significant and of similar magnitude for all participants in total duration. Hence, the error was noticed and eventually impacted similarly on all participants. Differences between participant groups emerged in gaze duration only. The over-regularisation effect was significant for typically developing children (intermediate and novice readers in Experiment 1, CA and RA controls in Experiment 2). However, neither adults (Experiment 1) nor dyslexic children (Experiment 2) showed the effect.

In typical development (Experiment 1), the structure of pseudo-homophones immediately disrupts lexical access. In contrast, over-regularisations had much less effect. This implies that the constituent morphemes are represented within the lexicon and are immediately parsed. This may speak to the debate about whether regular and irregular morphology are processed by the same, or distinct systems (e.g., Ullman, et al., 2005).

An alternative explanation is that the over-regularisations are sufficiently similar (orthographically and/or phonologically) to correct words to prevent an immediate disruption in processing. Unfortunately, in the present study the differences in orthographic overlap between pseudohomophones and over-regularisations limit our conclusions, as we cannot make direct comparisons between these conditions. However, it is unlikely that differences between pseudo-homophone and over-regularisation effects are due to purely orthographic processes. The experimental design actually resulted in larger orthographic differences between control and pseudowords for over-regularisations than for pseudo-homophones. This was unavoidable because of the nature of the language – irregular verbs often involve a change to the internal vowel. Over-regularisations differ from the correct verb in the internal vowel and the addition of a suffix (e.g., *grew-growed*). Pseudo-homophones were matched in orthographic features to the over-regularisations but the correct target differed. A hypothesis based on orthographic overlap in these two conditions would posit that the over-regularisation effect would be larger than the pseudo-homophone effect. Examining the β values for error (see Tables 2 and 3, Figures 1 and 2) suggests the contrary – the pseudoword effect is generally larger for pseudo-homophones than over-regularisations.

Regardless of the comparison between the pseudo-homophone and over-regularisation conditions, we provide consistent evidence that morphemes are processed rapidly even by novice typically developing readers (age 7-9 years). In fact, in Experiment 1, the morphological over-regularisation effect was significantly smaller in the gaze duration of adult readers compared to novice readers. This does not reflect adults overcoming the error more rapidly in general, as the difference was not significant in total duration. Rather, this implies that adults continue reading and later return to the word to check their interpretation. As suggested above, as adults encounter unknown words relatively rarely, making a 'best guess' about a word on the basis of available information and verifying that with surrounding context is likely to be an appropriate way to read. This fits within Grainger's (Grainger & Ziegler, 2011; Grainger et al., 2012) model of reading, as information from multiple fine and coarse grained codes contribute to word recognition. These codes must include morphemes, which initially enables word processing. However, eventually the over-regularisation is identified as a misspelling and the nearest match is chosen through word and sentence level processes. Other models of reading (e.g., Coltheart, 2006) don't adequately explain the contribution of morphemes or sentence level information in word recognition.

In gaze duration, the effect of morphological over-regularisation was significantly smaller for dyslexic children than RA children (but not significantly different from CA children). Differences between participant groups were not significant in total duration, although the effect appeared slightly increased for dyslexic children. Therefore, we suggest that children with dyslexia, like adults, also continue to read even though word recognition is incomplete. However, we argue this is for a different reason. Dyslexic children may well use context to support word recognition to a greater extent (Nation & Snowling, 1998). Elsewhere, we have shown that dyslexic children use lexical representations that lack morphological specificity, and may rely more heavily on root morphemes (and less on suffixes; Breadmore & Carroll, 2016a). This same argument could explain why the morphological over-regularisation effect is smaller for dyslexic children in gaze duration. Lexical access for the root is not disrupted in over-regularisations and, if this is dyslexic children's focus during word recognition, they would be expected to continue reading normally.

The effect that is observed later, in total duration, would therefore result from the syntactic anomaly that results from underspecified morphological processes.

*Syntactic processing*

As expected, in typical development (Experiment 1) and in dyslexia (Experiment 2) the effect of syntactic errors emerged even later than the effect of morphological over-regularisation. For adults and intermediate readers, it was significant only in total duration. Syntactic errors do not cause a failure in word recognition, it is the later sentence level processes that are disrupted. In typical development, this effect was larger for intermediate readers than adult or novice readers. Similar to the explanation posited for pseudo-homophones, intermediate readers are fast at reading correct verbs (like adults) but remain slow to recover from errors (like novice readers). Dyslexic children did not differ from RA or CA matched peers on the syntactic effect. We conclude, therefore, that dyslexic children's syntactic processing is not impaired.

Replication of findings with a range of different participant groups gives the present study broad generalizability across individuals. However, one limitation to these studies is generalizability across words. The number of items each individual participant read in each condition was relatively small. This was a necessary constraint due to the attentional limitations of novice readers. All targets were verb tense inflections. Future studies should examine a wider range of word types, morphemes (inflections, derivations, compounds), phonological units (syllables, onsets, rimes) and syntactic forms.

Unlike previous studies examining eye-movements in response to pseudo-homophones (Blythe et al., 2015; Jared et al., 1999; Rayner et al., 1998) we did not include a spelling control. It has previously been documented that pseudo-homophones offer a processing time advantage over spelling controls. However, over-regularisations can be decomposed using morphemes and pseudo-homophones can be decomposed using phonological decoding, both of which enable access to the correct lexeme. Spelling controls are a different type of error, as no strategy for decomposition will arrive at the correct target. Real word spelling controls are particularly problematic as there will be competition from other lexical features (e.g., semantics). Nonetheless, future research should replicate the present study and include a spelling control to test whether pseudo-homophones still offer a processing advantage relative to spelling controls in children with dyslexia. Since we found no significant effect of pseudo-homophones in first fixation duration, our hypotheses would be that dyslexic children would not show a pseudo-homophone advantage in these measures. Since dyslexic children showed smaller pseudo-homophone effects on total duration and smaller over-regularisation effects in gaze duration, we would expect to see the phonological advantage emerge.

There are many direct benefits to including a range of different error types in a within-subjects design (such as control over stimulus and participant factors) but an indirect benefit is the increase in ecological validity from disguising the aim of the experiment and reducing strategy use. In the current task pseudo-homophones accounted for only 12.5% of targets and so participants were unlikely to begin to use phonemic decoding strategically. After the experiment some adult participants commented that they had noticed a few mistakes in some of the sentences, as if they thought these were accidental and not by design. Hence although future studies may wish to replicate these findings with more items, caution should be taken not to disproportionately inflate the proportion of trials that contain errors. High rates of spelling errors may result in participants treating the task as a proof reading or spell-checking task, rather than real reading. This is of particular concern when sentence frames are repeated within an experiment, as in the present study, as carry-over effects may alter processing when reading the sentence for the second time. Previous research has shown that phonological and syntactic effects can vary between tasks (Kaakinen & Hyönä, 2010) and therefore future research should examine whether the present findings are replicated in other reading environments.

## Conclusion

Across adults, intermediate and novice typically developing readers, pseudo-homophones disrupted rapid lexical processing from first fixations whereas the effects of morphological over-regularisations and syntactic violations emerged later. Intermediate readers showed greater disruption due to errors, which we argue is adaptive for children who are still encountering many unknown words when reading. These developmental differences support a view that, in the age range we have tested, development involves gradual acquistion of additional processes that are increasingly used concurrently, rather than a qualitative shift. Children with dyslexia showed a smaller pseudo-homophone effect, significantly so in total duration. We argue that this is because dyslexic children relied heavily on phonological decoding, using the same strategies to read correct verbs and pseudo-homophones. Dyslexic children showed a smaller effect of over-regularisation but only in gaze duration. We argue that this is because dyslexic children do not fully process the morphological structure of the over-regularised verb. The component morphemes of the over-regularised verb enable them to obtain word meaning, possibly by focusing on the root morpheme. Children with dyslexia did not show differences in processing syntactic anomalies. Hence, our findings suggest that the difficulties shown by dyslexic individuals in this age group centre around the efficient development of automatic or coarse-grained word recognition skills, rather than difficulties specifically with decoding, or more widespread language difficulties.

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*Table 1: Descriptive statistics for all stimuli*

| | Syntax | Pseudowords (overall) | Paired samples t-test | Phonological | Morphological | Independent samples t-test |
|---|---|---|---|---|---|---|
| *Uninflected verb* | | | | | | |
| CELEX written frequency | | | | 501.9 (471.5) | 477.8 (461.0) | $t(34) = 0.2$, $p = .9$ |
| Length (N letters) | | | | 4.2 (0.6) | 4.1 (0.6) | $t(34) = 0.5$, $p = .6$ |
| *Error/pseudoword* | | | | | | |
| Bigram frequency (mean token) | 1641.2 (807.4) | 2157.5 (2471.6) | $t(35) = -1.1$, $p = .3$ | 1443.0 (1005.5) | 1839.3 (497.8) | $t(24.9) = -1.5$, $p = .1$ |
| Bigram frequency (mean type) | 137.0 (84.2) | 90.8 (112.6) | $t(35) = 1.8$, $p = .1$ | 123.6 (102.9) | 150.4 (60.2) | $t(27.4) = -1$, $p = .3$ |
| Length (N letters) | 6.0 (1.0) | 5.1 (1.4) | $t(35) = 3.5$, $p = .001$ | 5.9 (1.1) | 6.0 (0.9) | $t(34) = -0.2$, $p = .9$ |
| N characters before incorrect verb | 20.4 (6.4) | 20.4 (6.7) | $t(35) = 1.0$, $p = .3$ | | | |
| *Correct verb* | | | | | | |
| Length (N letters) | 5.6 (1.2) | 5.1 (1.4) | $t(35) = 1.8$, $p = .1$ | 6.3 (0.7) | 4.8 (1.0) | $t(34) = 5.4$, $p < .001$[a] |
| CELEX Written frequency | 124.1 (189.8) | 146.2 (185.5) | $t(35) = -0.9$, $p = .4$ | 79.1 (86.8) | 169.2 (249.6) | $t(21) = -1.4$, $p = .2$ |
| N characters before correct verb | 19.8 (6.7) | 20.4 (6.7) | $t(35) = 0.7$, $p = .5$ | 20.0 (5.7) | 20.8 (7.8) | $t(34) = -0.4$, $p = .7$ |
| N characters after verb | 17.8 (4.6) | 17.8 (4.6) | $t(35) = 1.0$, $p = .3$ | 18.7 (5.0) | 16.9 (4.0) | $t(34) = 1.2$, $p = .2$ |

*Note.* [a] It is not possible to match both the length of pseudowords and correct verbs because of the structure of the language – over-regularisations are necessarily always longer than their control. In contrast, pseudo-homophones involved substitution of a phoneme-grapheme correspondence and therefore contained a similar number of letters as controls; $t(17) = -1.9$, $p = .07$. Since the focus of this study was on pseudoword processing we matched the pseudowords but allowed the correct verbs to differ.

*Table 2: Experiment 1 LME model summary for pseudo-homophone, morphological over-regularisations and syntactic effects in adults, intermediate and novice readers.*

| Fixed effects | First fixation duration | | | Gaze duration | | | Total duration | | |
|---|---|---|---|---|---|---|---|---|---|
| | β | SE | t | β | SE | t | β | SE | t |
| *PSEUDO-HOMOPHONES* | [a] | | | [b] | | | [b] | | |
| (Intercept; adult correct verbs) | 209.26 | 9.55 | 21.92 | 224.81 | 17.73 | 12.68 | 305.99 | 38.62 | 7.92 |
| Intermediate reader | 35.03 | 13.11 | 2.67 | 71.40 | 22.35 | 3.19 | 141.32 | 44.01 | 3.21 |
| Novice reader | 71.92 | 12.30 | 5.85 | 181.92 | 22.34 | 8.14 | 329.04 | 44.22 | 7.44 |
| Verb error | 19.85 | 12.00 | 1.65 | 26.19 | 17.68 | 1.48 | 96.85 | 40.52 | 2.39 |
| Intermediate reader: Verb error | 4.45 | 15.59 | 0.29 | 42.39 | 22.98 | 1.84 | 252.77 | 52.62 | 4.80 |
| Novice reader: Verb error | 18.22 | 15.53 | 1.17 | 68.76 | 22.76 | 3.02 | 160.49 | 52.35 | 3.07 |
| *MORPHOLOGICAL OVER-REGULARISATIONS* | [a] | | | [a] | | | [c] | | |
| (Intercept; adult correct verbs) | 202.85 | 9.10 | 22.29 | 223.10 | 15.23 | 14.65 | 277.69 | 35.11 | 7.91 |
| Intermediate reader | 28.61 | 11.82 | 2.42 | 43.68 | 19.98 | 2.19 | 127.49 | 43.75 | 2.91 |
| Novice reader | 78.49 | 12.71 | 6.18 | 137.68 | 21.85 | 6.30 | 279.35 | 43.76 | 6.38 |
| Verb error | 5.03 | 10.03 | 0.50 | 12.27 | 14.38 | 0.85 | 76.16 | 32.02 | 2.38 |
| Intermediate reader: Verb error | 6.63 | 13.06 | 0.51 | 29.09 | 18.75 | 1.55 | 85.46 | 41.73 | 2.05 |
| Novice reader: Verb error | 4.64 | 13.03 | 0.36 | 75.84 | 18.72 | 4.05 | 85.89 | 41.46 | 2.07 |
| *SYNTACTIC ERRORS* | [a] | | | [a] | | | [b] | | |
| (Intercept; adult correct verbs) | 205.04 | 7.11 | 28.83 | 222.68 | 13.08 | 17.02 | 271.87 | 32.00 | 8.50 |
| Intermediate reader | 21.57 | 9.20 | 2.35 | 47.06 | 16.98 | 2.77 | 139.47 | 37.58 | 3.71 |
| Novice reader | 65.18 | 9.63 | 6.77 | 142.79 | 17.69 | 8.07 | 307.91 | 37.70 | 8.17 |
| Verb error | 8.00 | 7.22 | 1.119 | 11.40 | 10.22 | 1.12 | 95.70 | 27.80 | 3.44 |
| Intermediate reader: Verb error | 2.18 | 9.32 | 0.23 | 5.44 | 13.17 | 0.41 | 91.13 | 35.94 | 2.54 |
| Novice reader: Verb error | 0.65 | 9.29 | 0.07 | 1.90 | 13.18 | 0.14 | 44.22 | 35.90 | 1.23 |

*Note:* Contrast coding used to set adults as baseline for participant group (adults, intermediate, novice) and correct as baseline for verb (correct, incorrect). Fixed effects computed on raw data to provide β and SE values in msec. Only the fully specified model was fitted for raw data (not the null models). [a] ParticipantGroup*Verb +(1+Verb|Participant) +(1+ParticipantGroup|Item). [b] ParticipantGroup*Verb +(1+Verb|Participant) +(1|Item). [c] ParticipantGroup*Verb +(1|Participant) +(1|Item).

*Table 3: Likelihood ratio test statistics (on log transformed data) for pseudo-homophone, morphological over-regularisation and syntactic errors for each group of participants.*

| Experiment 1: | Adults | | | | Intermediate | | | | Novice | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fixed effects | $\chi2$ | df | $p$ | | $\chi2$ | df | $p$ | | $\chi2$ | df | $p$ | |
| *PSEUDO-HOMOPHONES* | | | | | | | | | | | | |
| First fixation duration | 8.31 | 1 | .0039 [a] | ** | 5.94 | 1 | .0148 | * | 11.20 | 1 | .0008 [a] | ** |
| Gaze duration | 8.25 | 1 | .0041 [a] | ** | 15.95 | 1 | .00007 | ** | 17.78 | 1 | .00002 | ** |
| Total duration | 17.56 | 1 | .00003 | *** | 55.66 | 1 | < .00001 | *** | 28.65 | 1 | < .00001 | *** |
| *MORPHOLOGICAL OVER-REGULARISATIONS* | | | | | | | | | | | | |
| First fixation duration | 1.14 | 1 | .2847 | | 1.58 | 1 | .2085 [a] | | 1.50 | 1 | .2204 [a] | |
| Gaze duration | 2.14 | 1 | .1438 | | 15.07 | 1 | .0001 [a] | *** | 24.98 | 1 | < .00001 | *** |
| Total duration | 18.65 | 1 | .00002 | *** | 44.03 | 1 | < .00001 [a] | *** | 21.63 | 1 | < .00001 | *** |
| *SYNTACTIC ERRORS* | | | | | | | | | | | | |
| First fixation duration | 1.85 | 1 | .1739 | | 2.46 | 1 | .1169 | | 0.75 | 1 | .3855 | |
| Gaze duration | 1.67 | 1 | .1967 | | 3.67 | 1 | .0554 | . | 0.98 | 1 | .3229 | |
| Total duration | 61.72 | 1 | < .00001 [a] | *** | 37.27 | 1 | < .00001 | *** | 17.34 | 1 | .00003 | *** |
| Experiment 2: | Dyslexia | | | | CA | | | | RA | | | |
| Fixed effects | $\chi2$ | df | $p$ | | $\chi2$ | df | $p$ | | $\chi2$ | df | $p$ | |
| *PSEUDO-HOMOPHONES* | | | | | | | | | | | | |
| First fixation duration | 0.73 | 1 | .3937 | | 2.48 | 1 | .11510 [a] | | 3.41 | 1 | .06494 [a] | . |
| Gaze duration | 3.82 | 1 | .05079 | . | 10.89 | 1 | .00097 [a] | *** | 6.29 | 1 | .01214 | * |
| Total duration | 10.58 | 1 | .00114 | ** | 28.14 | 1 | < .00001 | *** | 25.20 | 1 | < .00001 | *** |
| *MORPHOLOGICAL OVER-REGULARISATIONS* | | | | | | | | | | | | |
| First fixation duration | 0.03 | 1 | .86750 [a] | | 2.68 | 1 | .10150 | | 1.03 | 1 | .30990 | |
| Gaze duration | 2.83 | 1 | .09273 | . | 7.02 | 1 | .00806 | ** | 21.14 | 1 | < .00001 [a] | *** |
| Total duration | 10.47 | 1 | .00122 | ** | 9.47 | 1 | .00209 | ** | 6.28 | 1 | .01223 | * |
| *SYNTACTIC ERRORS* | | | | | | | | | | | | |
| First fixation duration | 0.04 | 1 | .83310 | | 2.19 | 1 | .13850 | | 0.01 | 1 | .94020 | |
| Gaze duration | 0.15 | 1 | .70250 | | 2.51 | 1 | .11330 | | 0.40 | 1 | .52670 | |
| Total duration | 9.42 | 1 | .00215 | ** | 16.99 | 1 | .00004 | *** | 6.79 | 1 | .00915 | ** |

*Note:* Likelihood ratio tests computed on log transformed data. The initial full model was Verb +(1+Verb|Participant) +(1|Item). Bonferroni correct criterion .05/3 = .167. [a] All random slopes removed; Verb +(1|Participant) +(1|Item).

*Table 4: LME model summary statistics for pseudo-homophone, morphological over-regularisation and syntactic errors for dyslexic, CA and RA children.*

| | First fixation duration | | | Gaze durations | | | Total durations | | |
|---|---|---|---|---|---|---|---|---|---|
| Fixed effects | β | SE | t | β | SE | t | β | SE | t |
| *PSEUDO-HOMOPHONES* | [b] | | | [a] | | | [a] | | |
| (Intercept; dyslexic correct verbs) | 300.55 | 12.38 | 24.28 | 520.21 | 30.36 | 17.13 | 785.50 | 61.76 | 12.72 |
| Chronological age matched | -63.30 | 17.55 | -3.61 | -245.19 | 41.52 | -5.91 | -349.41 | 74.82 | -4.67 |
| Reading age matched | -10.02 | 17.51 | -0.57 | -95.62 | 39.99 | -2.39 | -124.18 | 75.25 | -1.65 |
| Verb error | -10.12 | 15.95 | -0.64 | 84.22 | 27.51 | 3.06 | 167.99 | 48.05 | 3.50 |
| Chronological age matched: Verb error | 31.93 | 22.76 | 1.40 | -18.97 | 39.38 | -0.48 | 106.58 | 69.35 | 1.54 |
| Reading age matched: Verb error | 41.97 | 22.63 | 1.90 | 0.89 | 38.79 | 0.02 | 185.16 | 68.19 | 2.72 |
| | | | | | | | | | |
| *MORPHOLOGICAL OVER-REGULARISATIONS* | [c] | | | [a] | | | [a] | | |
| (Intercept; dyslexic correct verbs) | 301.06 | 14.54 | 20.70 | 466.90 | 32.22 | 14.49 | 651.95 | 51.84 | 12.58 |
| Chronological age matched | -73.54 | 20.18 | -3.64 | -213.39 | 38.29 | -5.57 | -272.43 | 67.86 | -4.02 |
| Reading age matched | -24.73 | 20.16 | -1.23 | -125.40 | 37.18 | -3.37 | -35.30 | 67.06 | -0.53 |
| Verb error | 21.04 | 16.15 | 1.30 | 77.53 | 24.88 | 3.12 | 246.59 | 56.35 | 4.38 |
| Chronological age matched: Verb error | 4.93 | 23.10 | 0.21 | -22.16 | 35.18 | -0.63 | -118.04 | 80.08 | -1.47 |
| Reading age matched: Verb error | -8.23 | 23.04 | -0.36 | 26.98 | 35.33 | 0.76 | -99.02 | 79.80 | -1.24 |
| | | | | | | | | | |
| *SYNTACTIC ERRORS* | [c] | | | [b] | | | [a] | | |
| (Intercept; dyslexic correct verbs) | 296.18 | 11.60 | 25.54 | 456.10 | 25.63 | 17.79 | 667.97 | 48.59 | 13.75 |
| Chronological age matched | -75.32 | 16.39 | -4.60 | -198.44 | 33.49 | -5.93 | -280.55 | 61.51 | -4.56 |
| Reading age matched | -35.65 | 16.33 | -2.18 | -91.34 | 33.25 | -2.75 | -17.85 | 60.60 | -0.30 |
| Verb error | 5.47 | 9.37 | 0.58 | 3.58 | 14.79 | 0.24 | 155.67 | 36.50 | 4.27 |
| Chronological age matched: Verb error | 5.61 | 13.40 | 0.42 | 12.63 | 21.06 | 0.60 | -32.30 | 51.86 | -0.62 |
| Reading age matched: Verb error | 0.07 | 13.33 | 0.01 | 12.73 | 21.03 | 0.61 | -12.93 | 51.91 | -0.25 |

*Note:* Contrast coding used to set dyslexic children as baseline for participant group and correct as baseline for verb. Fixed effects computed on raw data to provide β and SE values in msec. Only the fully specified model was fitted for raw data (not the null models). [a]

ParticipantGroup*Verb +(1+Verb|Participant) +(1+ParticipantGroup|Item). [b] ParticipantGroup*Verb +(1+Verb|Participant) +(1|Item). [c] ParticipantGroup*Verb +(1|Participant) +(1|Item).

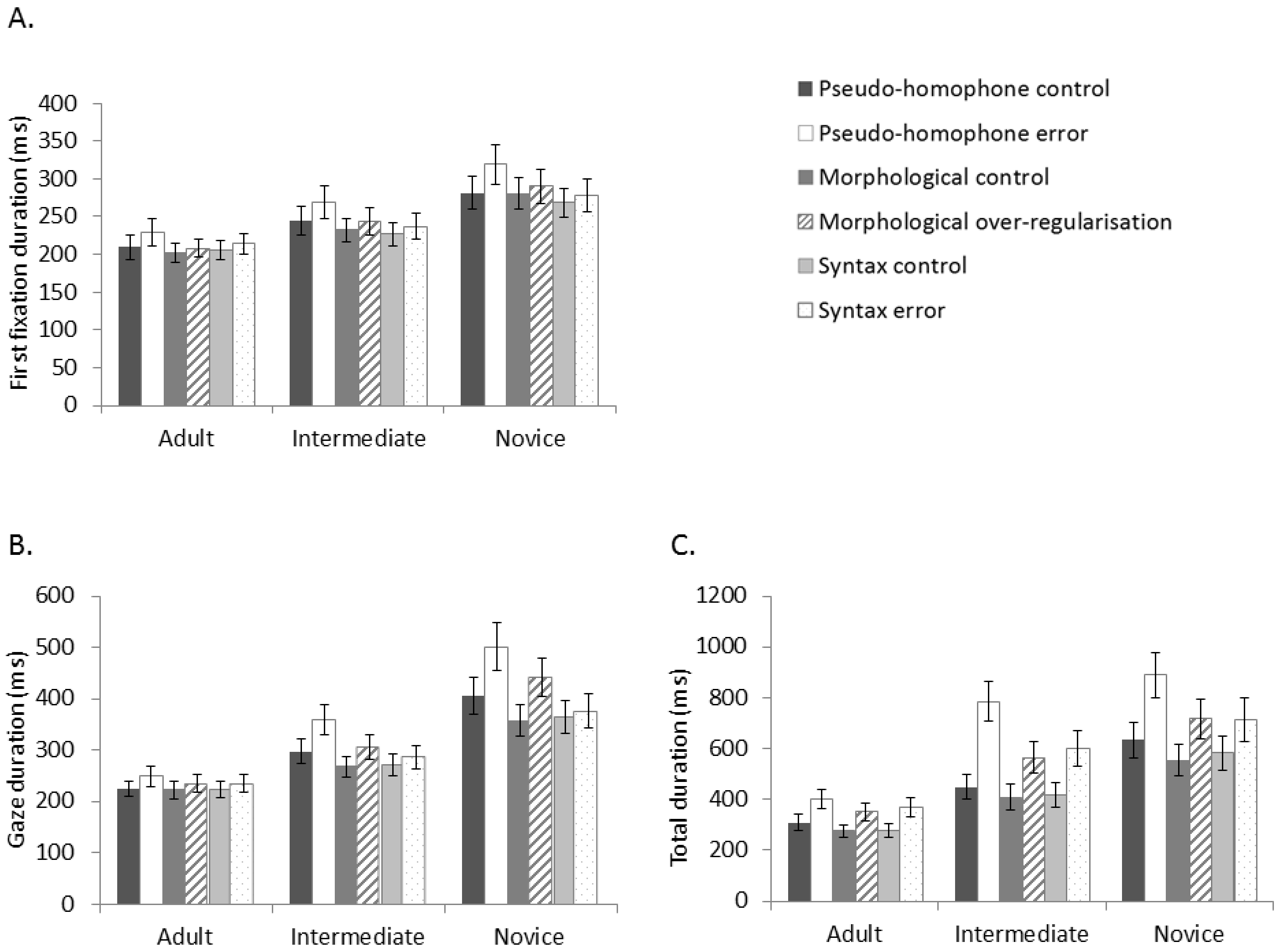


Figure 1: Mean first fixation, gaze and total duration (in msec) of adult, intermediate and novice readers while reading correct targets and incorrect targets that are pseudo-homophones, over-regularisations or syntactic errors (Experiment 1).

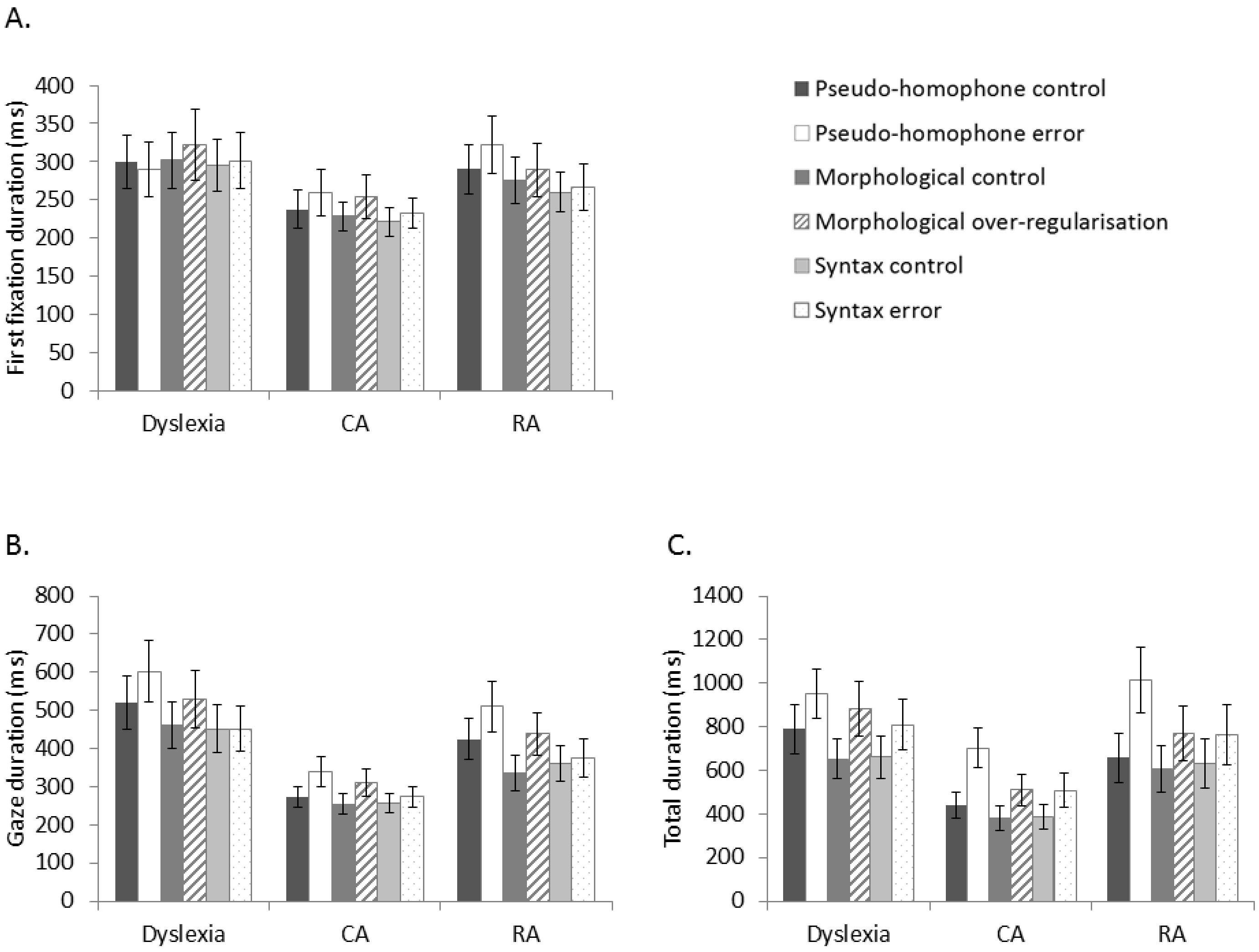


Figure 2: Mean first fixation, gaze and total duration (in msec) of children with dyslexia, chronological-age (CA) matched and reading-age (RA) peers while reading correct targets and incorrect targets that are pseudo-homophones, over-regularisations or syntactic errors (Experiment 2).

Appendix 1: List of Stimuli

| Word Error/Control/Syntax error | Syntax Control |
| --- | --- |
| *Morphological* | |
| The spider will have spinned/spun/spinning a huge web | The spider is spinning a huge web |
| Bill will have knowed/known/knew about the fallen tree | Bill knew about the fallen tree |
| Yesterday Richard digged/dug/dig a deep hole for the tree | Tomorrow Richard will dig a deep hole for the tree |
| Earlier the sharks swimmed/swam/swim past the divers | Sometimes the sharks swim past the divers |
| Last year the planes flyed/flew/flown right past their house | Last year the planes had flown right past their house |
| Last Sunday the school choir singed/sang/sing in the church | Sometimes the school choir sing in the church |
| Where has he hidded/hidden/hiding the chocolate? | Where is he hiding the chocolate? |
| The baby's parents had not sleeped/slept/sleeping properly for weeks | The baby's parents won't be sleeping properly for weeks |
| The waiter gived/gave/given mum the bill | The waiter had given mum the bill |
| Yesterday the fishermen catched/caught/catch a lot of fish | Often the fishermen catch a lot of fish |
| The girl holded/held/hold her mum's hand | The girl will hold her mum's hand |
| Last Friday the teacher beginned/began/begin the lesson with a game | Usually the teacher will begin the lesson with a game |
| For Gemma's birthday last year her mum maked/made/make her a huge cake | For Gemma's birthday her mum will make her a huge cake |
| The flowers have always growed/grown/grew by the front door | The flowers always grew by the front door |
| She had writed/written/wrote a long letter | Yesterday she wrote a long letter |
| The nurse asked if he had taked/taken/taking his medicine | The nurse asked if he was taking his medicine |
| Sophie will not have eated/eaten/ate all of her dinner | Sophie ate all of her dinner |
| Sue and Hannah have never rided/ridden/riding a horse before | Sue and Hannah were riding a horse before |

| Word Error/Control/Syntax error | Syntax Control |
|---|---|
| *Phonological* | |
| The penguins were slyding/sliding/slide across the ice | The penguins can slide across the ice |
| How are you trayning/training/train the dog? | How will you train the dog? |
| Last Summer the gardener wartered/watered/water the flowers in the park | In Summer the gardener will water the flowers in the park |
| The children have klimed/climbed/climb to the top of the tree | The children climb to the top of the tree |
| Jacob's Mum will be torking/talking/talk to the teacher later | Jacob's Mum will talk to the teacher later |
| Last year Billy always wurked/worked/working hard in class | Last year Billy was always working hard in class |
| Earlier in the book Cinderella whished/wished/wish for a fairy godmother | Later in the book Cinderella will wish for a fairy godmother |
| The village shop will have clozed/closed/close by tea time | The village shop will close by tea time |
| Tom and Eva had plaied/played/playing together often | Tom and Eva were playing together often |
| Last Autumn Ben and Sally pickt/picked/pick all of the blackberries | In Autumn Ben and Sally pick all of the blackberries |
| Last year the school play endid/ended/end with a big dance | This year the school play will end with a big dance |
| Last week Alfie's Mum bookt/booked/book a holiday to Spain | This week Alfie's Mum will book a holiday to Spain |
| The bird will have nestid/nested/nesting in the tree by the house | The bird is nesting in the tree by the house |
| Dad hadn't parkt/parked/parking the car yet | Dad hadn't finished parking the car yet |
| Earlier the rabbit hopt/hopped/hop around in the sunshine | Later the rabbit will hop around in the sunshine |
| Yesterday the buses stopt/stopped/stop outside the library | Usually the buses stop outside the library |
| Dylan has wantid/wanted/wanting a bike for years | Dylan has been wanting a bike for years |
| The poor dog had barkt/barked/barking to be let out of the car | The poor dog was barking to be let out of the car |